Universiteit Utrecht
Faculty of Geosciences

Research group
River and delta morphodynamics

Assessing instability of river bifurcations and flood risk division over deltas

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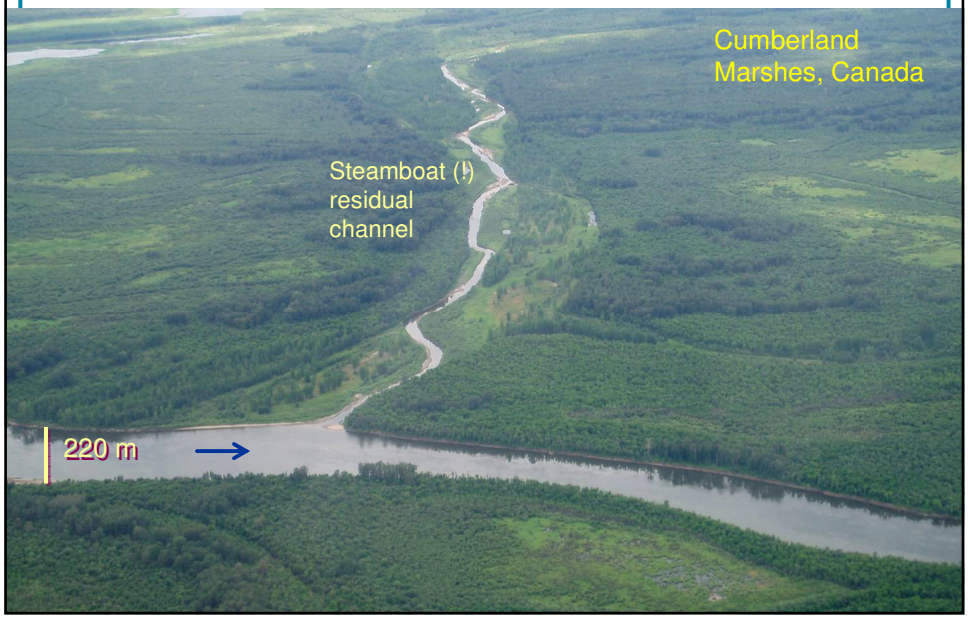
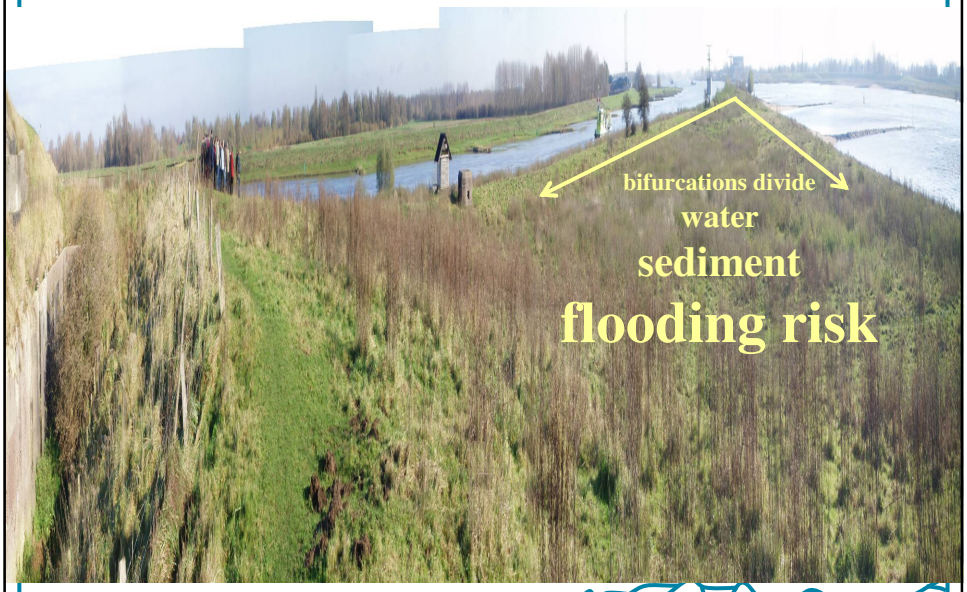
Main messages:

- bifurcations: diffluence, avulsion, offtake, diversion, branches, delta tributaries
- river bifurcations unstable!
  → one river branch closes, other enlarges
  - unless...
- effect of bifurcation both downstream and upstream!

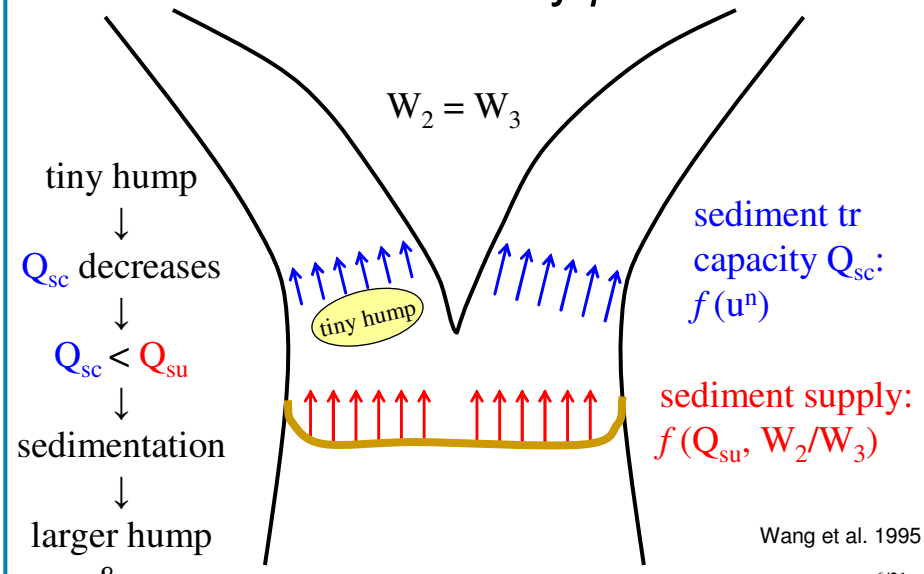
Avulsions: saskatchewan river



Societal relevance



Bifurcation instability *prima facie*



Wang et al. 1995

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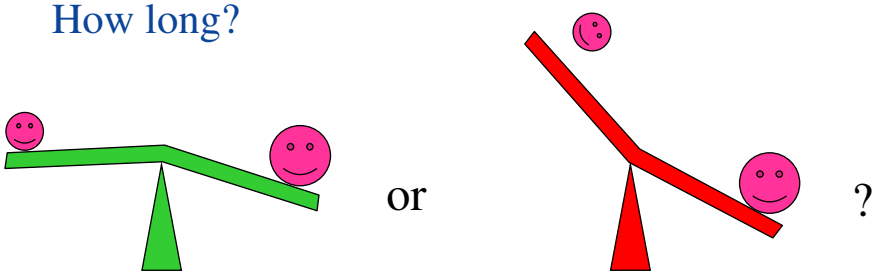
Problem definition

- Can bifurcations be stable with ~symmetrical division of flow? How long?



- Effects downstream? upstream?

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Physics-based numerical models:

- bifurcation unbalanced by
  - gradient difference
  - upstream bend or bars
- bifurcations nearly always unstable!
  - model based on laws for fluid flow, sediment transport, mass conservation

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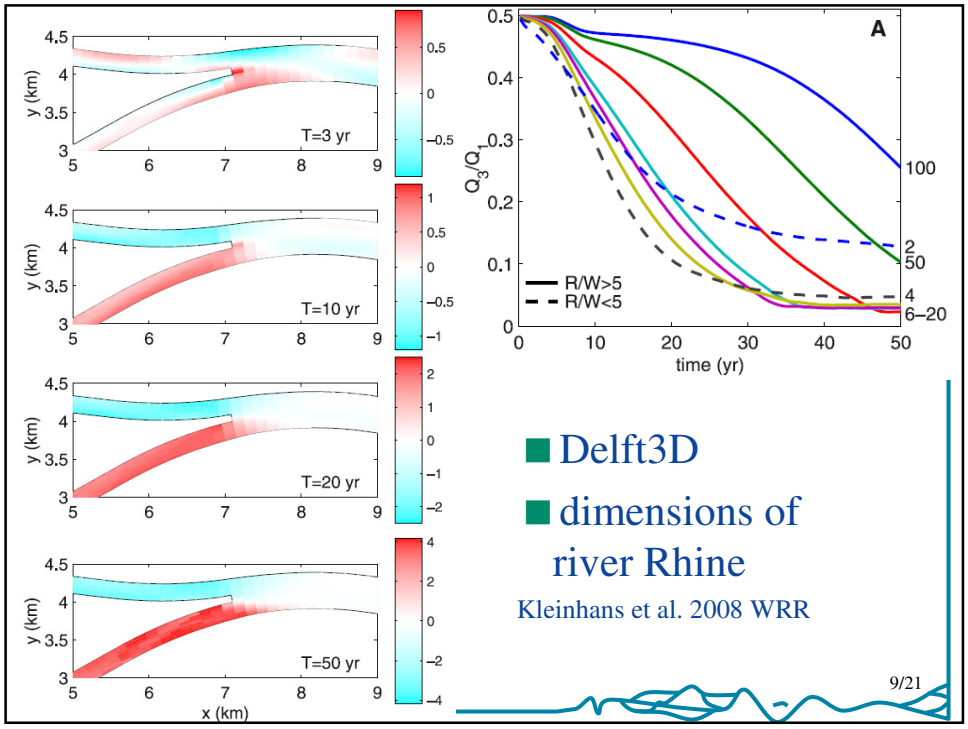
T=3 yr
T=10 yr
T=20 yr
T=50 yr
y (km)
x (km)
A
Q_3/Q_1
time (yr)
R/W>5
R/W<5
100
2
50
4
6–20
Delft3D
dimensions of river Rhine
Kleinhans et al. 2008 WRR
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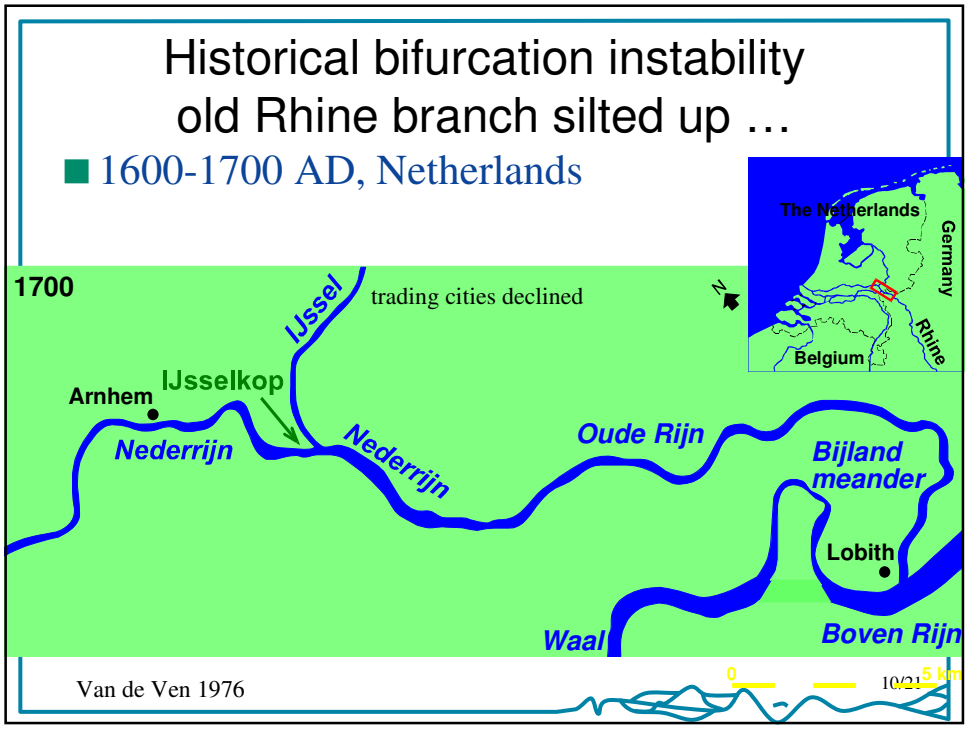
Historical bifurcation instability
old Rhine branch silted up …
1600-1700 AD, Netherlands
1700
trading cities declined
IJssel
IJsselkop
Arnhem
Nederrijn
Nederrijn
Oude Rijn
Bijland meander
Lobith
Waal
Boven Rijn
The Netherlands
Germany
Belgium
Rhine
N
0
5 km
Van de Ven 1976
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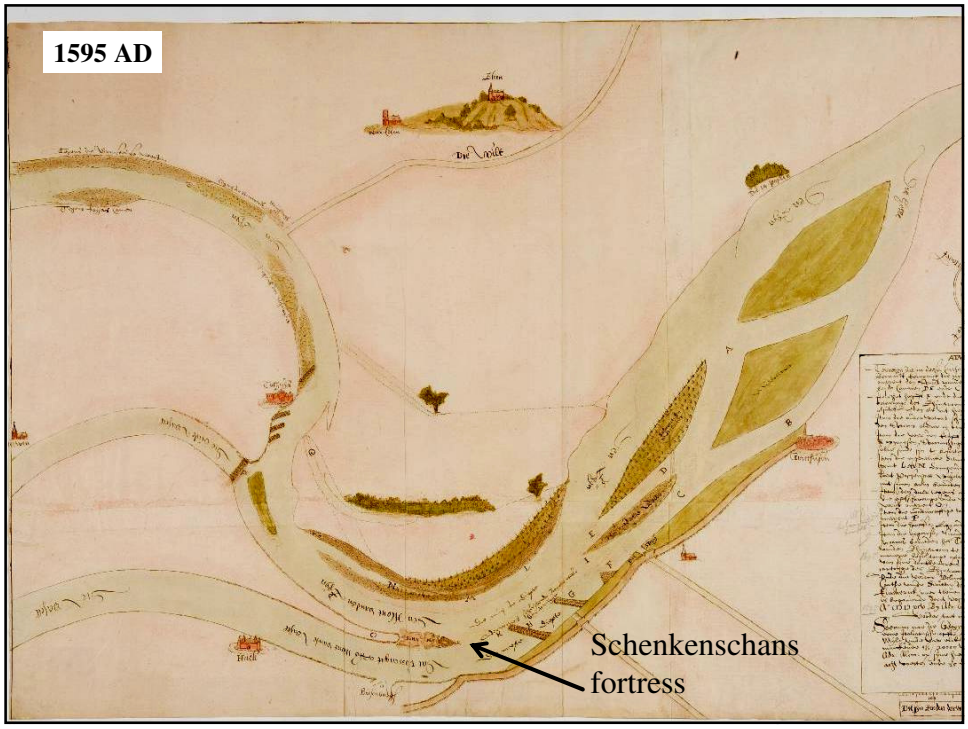
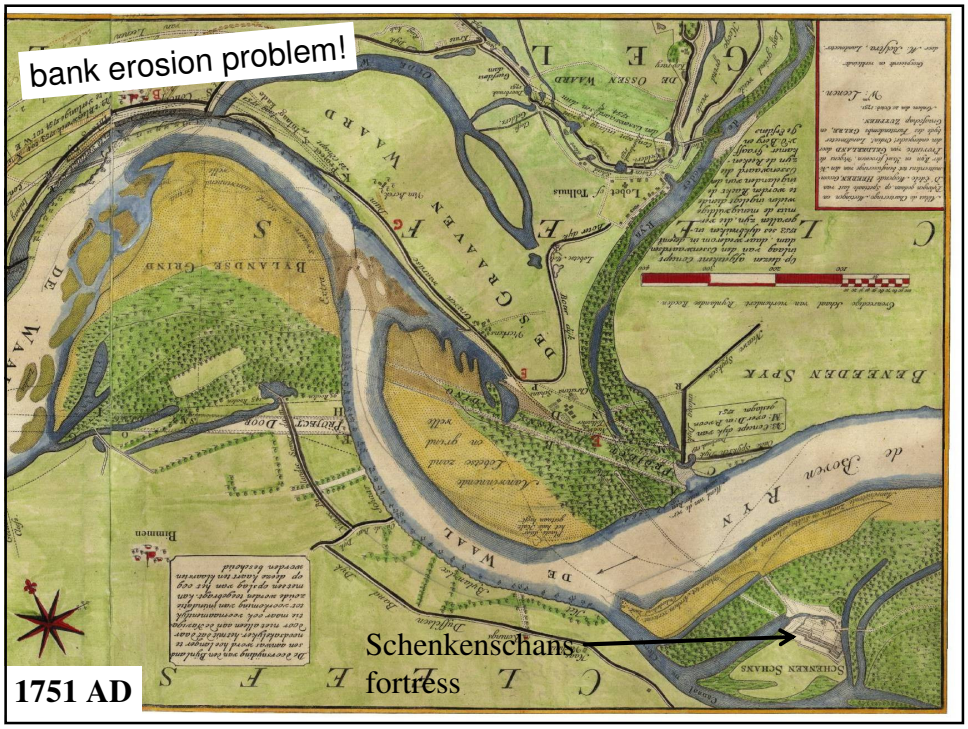
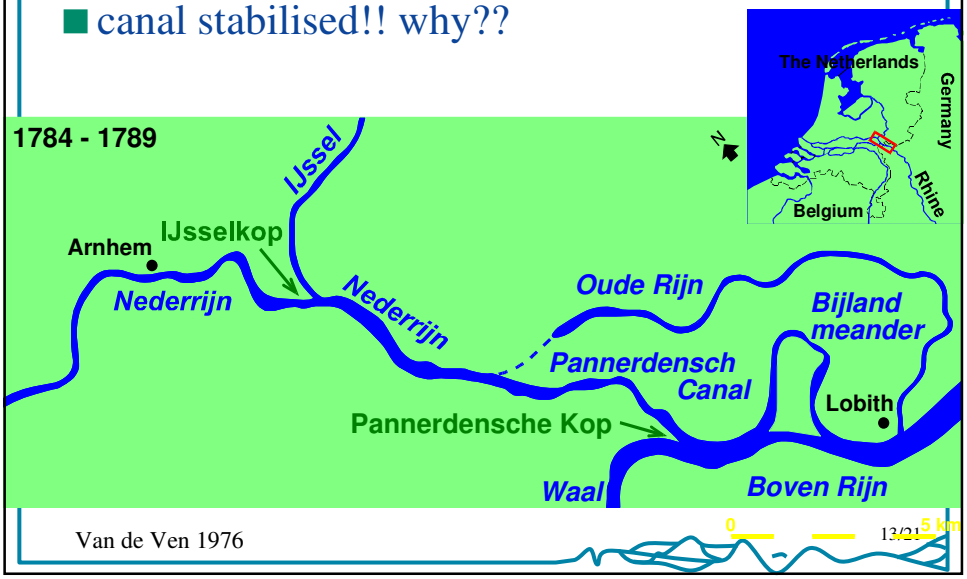

1595 AD
Schenkenschans
fortress


bank erosion problem!
Schenkenschans
fortress
1751 AD

… so we dug a bypass canal (1707 AD)

- canal stabilised!! why??



Van de Ven 1976

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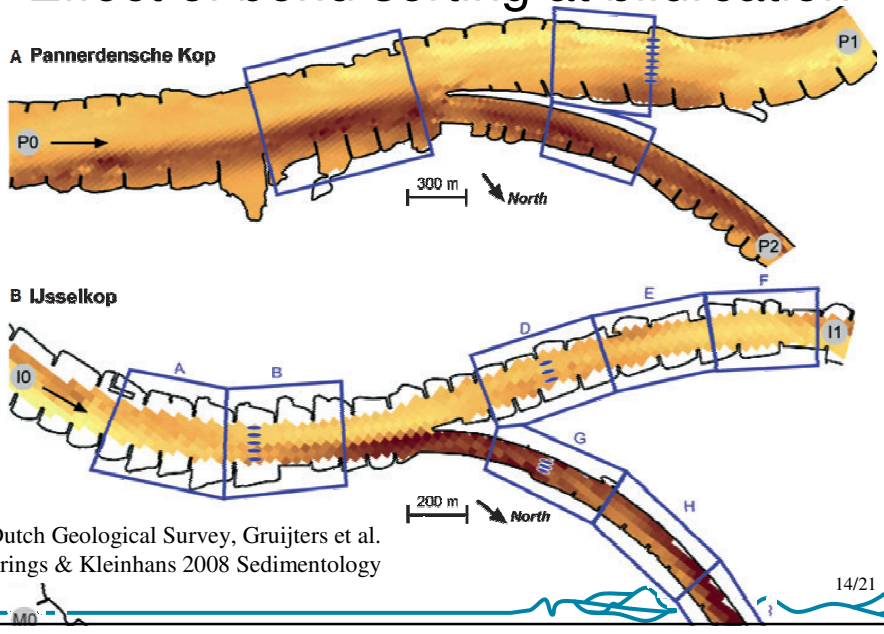
Effect of bend sorting at bifurcation



Dutch Geological Survey, Gruijters et al.
Frings & Kleinhans 2008 Sedimentology

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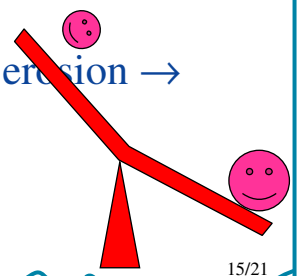
Only Dutch bifurcations are stable!!??

- bed surface of enlarging canals very coarse
  - erosion → armouring (coarse surface layer)
  - banks protected since 1800s
  - no armouring (downstream bifurcation Merwede) → unstable bifurcation!
- banks *and* bed protected against erosion → bifurcation ***accidentally*** stable → don't touch!!!



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Use river diversion to build land?

- downstream effects:
  - change in discharge
  - sedimentation / erosion
- upstream effects of bifurcation??
- an old lesson: 1421 AD flooding disaster

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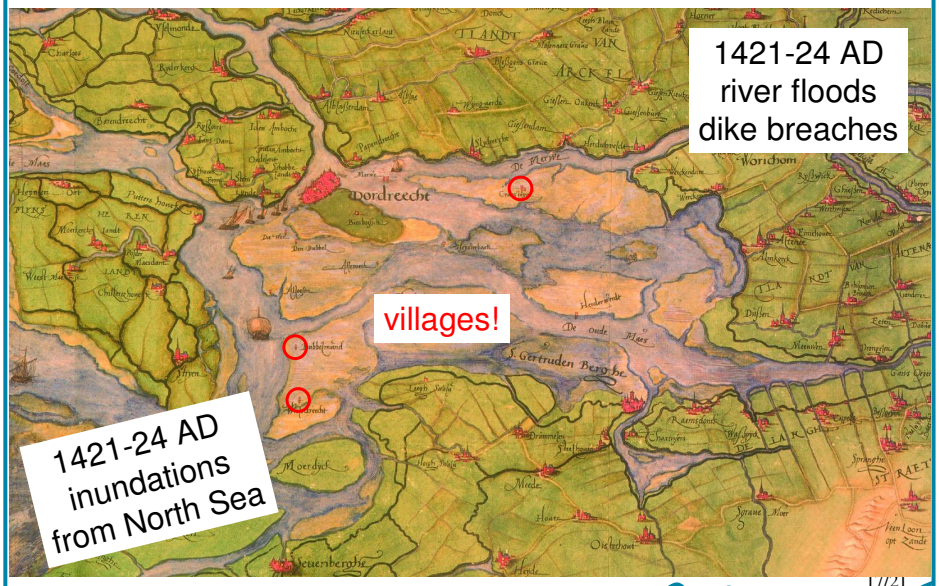
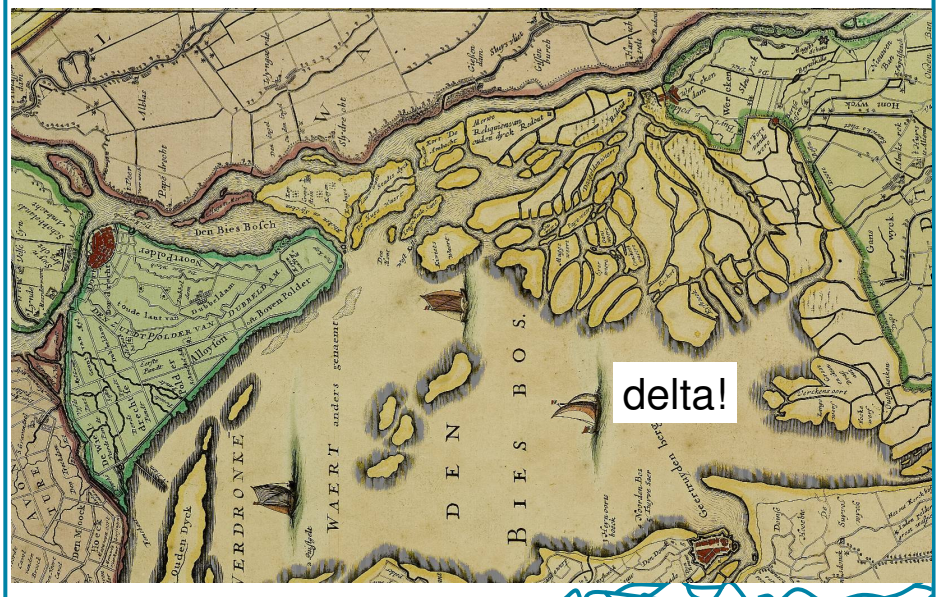
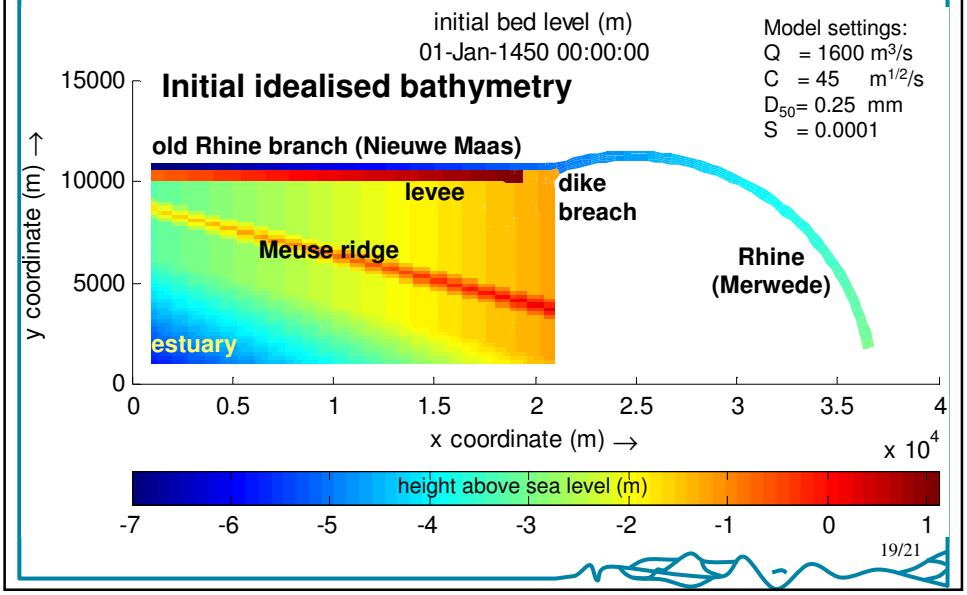
Historical map 1568 AD



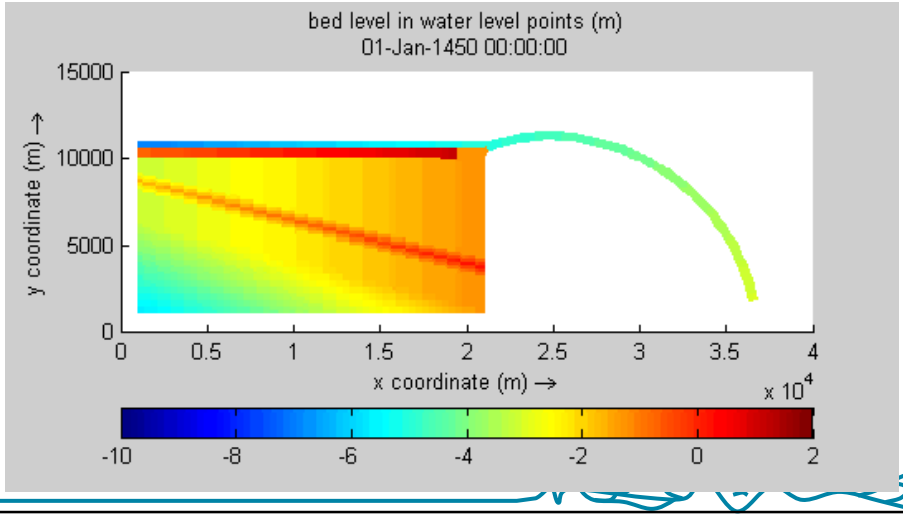
Historical map 1639 AD



Delft3D modelling



higher flood water levels →
exacerbated by ice dams and vegetation
→ numerous dike breaches



Conclusions

- bifurcations are not stable
  - except in exceptional conditions → dangerous!
- effects downstream:
  - changing division of water and flooding risk
  - sedimentation and erosion problems
- effects upstream:
  - higher flood water levels

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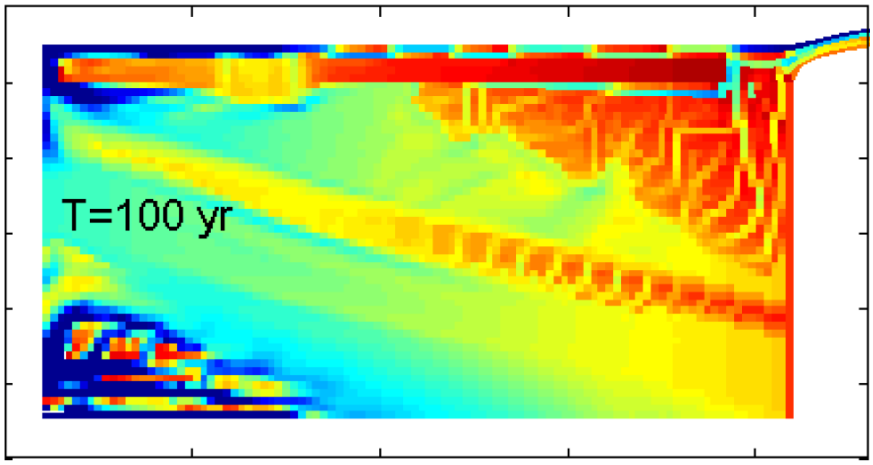

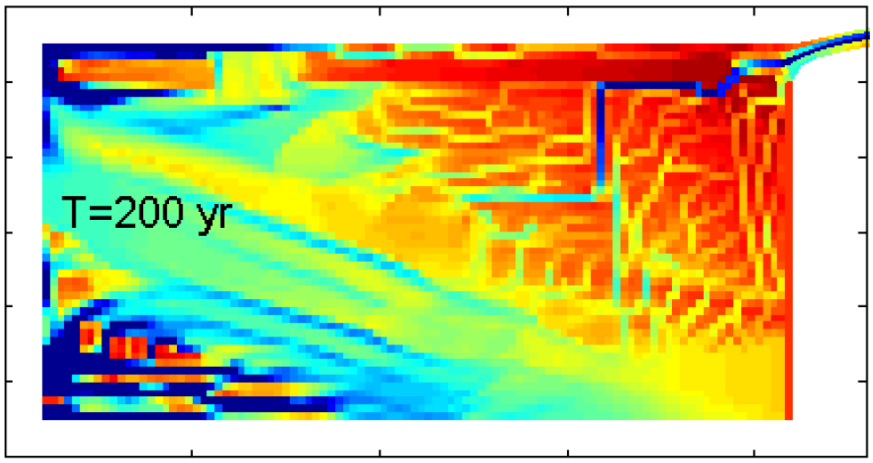

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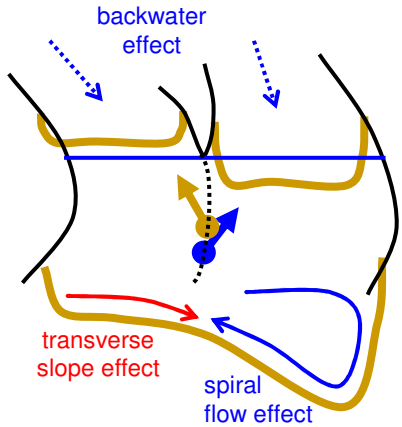
New nodal point relation for bends

- shear stress **vector**
  versus
  sediment transport vector
- backwater effects
- transverse slope effect (gravity)
  (Ikeda et al. 1981; Bolla Pitaluga et al. 2003)
- spiral flow effect
  (Struiksma et al. 1985; Talmon et al. 1995; Kleinhans et al. 2008)



→ unbalancing transport nonlinearity, balancing transverse slope, unbalancing spiral flow

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